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Socio-Cognitive Factors in the Acquisition and Transfer of Knowledge

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Abstract: Within cooperative learning great emphasis is placed on the benefits of ætwo heads being greater than oneÆ. However, further examination of this adage reveals that the value of learning groups can often be overstated and taken for granted for different types of problems. When groups are required to solve ill-defined and complex problems under real world constraints, different socio-cognitive factors (e.g., metacognition, collective induction, and perceptual experience) are expected to determine the extent to which cooperative learning is successful. Another facet of cooperative learning, the extent to which groups enhance the use of knowledge from one situation to another, is frequently ignored in determining the value of cooperative learning. This paper examines the role and functions of cooperative learning groups in contrast to individual learning conditions, for both an acquisition and transfer task. Results for acquisition show groups perform better overall than individuals by solving more elements of the Jasper problem as measured by their overall score in problem space analysis. For transfer, individuals do better overall than groups in the overall amount of problem elements transferred from Jasper. This paradox is explained by closer examination of the data analysis. Groups spend more time engaged with each other in metacognitive activities (during acquisition) whereas individuals spend more time using the computer to explore details of the perceptually based Jasper macrocontext. Hence, results show that individuals increase their perceptual learning during acquisition whereas groups enhance their metacognitive strategies. These investments show different pay-offs for the transfer problem. Individuals transfer more overall problem elements (as they explored the context more) but problem solvers who had the benefit of metacognition in a learning group did better at solving the most complex elements of the transfer problem. Results also show that collective induction groups (ones that freely share) – in comparison to groups composed of dominant members – enhance certain kinds of transfer problem solving (e.g., generating subgoals). The results are portrayed as the active interplay of socio-cognitive elements that impact the outcomes (and therein success) of cooperative learning.

Keywords: Cooperative learning; Knowledge acquisition; Perpetual context; Situated cognition; Social processes; Transfer of knowledge

INTRODUCTION

As the US Air Force encounters new domains with hard challenges it is increasingly recognised that multidisciplinary teams are a primary means for generating meaning in complex situations, acquiring and sharing knowledge, coordinating resources, making decisions, solving problems and executing actions. Conventional wisdom suggests that in some cases 'many hands make light work' while in others 'too many cooks spoil the broth'. Determining whether teamwork is effective and efficient requires an understanding of the social and cognitive foundations of teamwork. Inherent in teamwork is how individual and team cognition affect learning. The remainder of the paper uses the term *learning* to specifically refer to: (a) the acquisition of the knowledge and (b) the transfer of knowledge from one situation to another.

Research in this area can be an important consideration in the design of emerging collaborative technologies (e.g., datawalls, groupware computing).

This paper's objective is to examine individual and cooperative learning through the lens *of socio-cognitive factors*. Socio-cognitive factors help team members make sense of a situation, converge multiple perspectives towards a solution, and transfer knowledge from one context to another. The study of socio-cognitive factors in learning is inextricably tied to: (a) understanding context, (b) defining and knowing what the team cognitive demands are for a given context (as represented by specific experimental tasks/scaled world simulations), (c) operational definition of what a team consists of in terms of levels of experience, role interdependencies, type of subjects used and joint actions required for specified tasks, (d) requirements emerging through the interaction of teamwork, taskwork and context and (e) the methods and measures used to assess items a–d. Cooperative learning may be approached from various directions inclusive of historical, theoretical, methodological and practical significance. Given these constraints this paper looks at three research questions:

1. Do cooperative learning groups do better than individuals at solving complex problems?

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2. How do cooperative and individual learning processes differentially affect transfer to similar problems?
3. What circumstances make cooperative learning valuable? How do socio-cognitive factors influence learning processes?

Theoretical Perspectives on Cooperative Learning

In many cases there is a *historical basis* for success in cooperative learning (CL). When problem solvers cooperate as a group, many positive benefits can accrue (e.g., Dansereau 1988; Fletcher 1985; Gabbert et al 1986; Johnson et al 1986; Slavin 1983). The underlying rationale of having people *work in groups* is that in some cases groups do no worse than individuals (with the added benefit that there are social advantages of members getting to know one another), but in most cases groups do better than individuals. This is reinforced by many past reviews of cooperative learning (Johnson and Johnson 1985; Johnson et al 1983; Slavin 1983). However, there is disagreement as to the underlying reasons accounting for success. Many researchers in the social psychology/team literature account for success by looking at different variables, methodologies, constraints and measures. Integrated views are typically cast as general team theories or frameworks (e.g., see Davis 1969; Hackman and Morris 1975; Kelley and Thibaut 1969; McGrath 1984; Roby 1968). More recently, theories exploring team cognition have been posed (e.g., Cannon-Bowers et al 1993; Hinsz et al 1997; Klimoski and Mohammed 1994; Rentsch and Hall 1994). Some focus on schema for shared cognition (e.g., Rentsch and Hall 1994); others on group memory (Moreland et al 1996) and group information processes (Hinsz et al 1997), while others emphasise the role of meaning and the social construction of knowledge (Nosek and McNeese 1997). This paper takes the position that cognitive benefits accrue when individual team members share knowledge through cooperative processes. Hence, team cognition theories that highlight group schema, information processes, memory and meaning are salient for distilling the socio-cognitive factors that determine learning success. Three *basic-level processes* are predicted to form the basis for acquiring, constructing, transferring and remembering knowledge: collective induction, generative learning and metacognition.

Collective Induction

One theoretical position – collective induction (Laughlin 1989) – is useful to consider for comparing individual and team cognition when it comes to learning. Collective induction is a group cognitive process that reinforces synergistic interaction among group members such that ideas, knowledge and strategies are disseminated to each member. Inherently, one member learns through collective participation with other members above and beyond what they could have learned by themselves. Laughlin describes the process as a collective search for descriptive, predictive or explanatory generalisations, rules or principles. Inherent within this theory is the idea that group problem solving consists of individual responses being mapped into a collective response through social combination processes (e.g., majority, minority, truth wins). Collective induction is specified for a continuum of problem-solving/decision-making activities that are anchored by intellective and judgement tasks. An intellective task contains a correct solution wherein verbal or quantitative arguments can enact agreement in the form of a collective response. Judgemental tasks involve evaluation, behaviour or consensus for which there is no demonstrably correct solution. In many complex requirements involving Air Force teamwork (e.g., command and control) both a mixture of intellective and judgement tasks exist.

Collective induction may be viewed as a form of *generative learning* as members engage in active discussions and explanations rather than just passively receive information. Each member's generative learning affords him or her additional insights that are consequently integrated into cooperative activities to increase overall understanding. Hence, the give and take among members causes a synergism to transpire. Alternatively, this is described in other arenas as the *social construction of knowledge* (Bereiter and Scardamalia 1989) resulting in *group sensemaking* (Weick 1995).

A key concept within collective induction that needs to be assessed is the level of synergy experienced among group members. For example, some group members freely share and are equivalent in their contributions. In other situations, a dominant member may lead the group. The dominant member is typically defined as the one who talks the most during learning activities. The dominant group classification for the studies reported in this paper is defined as when one member generates more than or equal to 66% of the total words in the team's transcript; whereas if neither member generates more than or equal to 66% of the total words they are classified as shared groups. For borderline cases, secondary criteria consisted of using subjective ratings of the video observation data to assign teams to either category.

When a dominant member is present it is hypothesised that collective induction is less likely to occur. Cooperative learning without collective induction may not be very effective especially when it comes to group members transferring knowledge to similar situations. In contrast, certain cooperative learning/group problem-solving tasks may benefit more from a strong leadership component in the group (assuming that a leader has the requisite skills, knowledge, context to lead). Hence, it is possible that a dominant member may actually help a team more than shared equally weighted contributions from members (Kimble and McNeese 1987). Hence, our research is interested in comparing these different types of groups and how they might contrast to individual learning settings – as assessed for both acquiring and transferring knowledge.

Metacognition

Metacognitive strategies allow people to plan and assess their own cognitive behaviour (elaborating ideas, monitoring errors and planning remedial actions). They have facilitated successful problem solving (Palincsar and Brown 1984) and knowledge transfer (Dansereau 1988) for different domains. One hypothesis this paper looks at is that groups may naturally produce metacognitive strategies, in contrast to individual problem solvers. It is expected that cooperative learning groups will enhance metacognitive strategies in team members and therein improve abilities of the group to successfully solve problems. The prediction also suggests that if groups develop collective induction then they *naturally* develop metacognitive strategies as part of their problem-solving style (in contrast to individuals), when working on ill-defined, complex problems.

Transfer of Knowledge

Bransford and his colleagues have shown that knowledge is less likely to remain inert and is more likely be spontaneously accessed for future endeavours (Bransford et al 1988) when knowledge is generated as part of problem solving (generative learning). The prediction is that collective induction and metacognition actively produce generative learning and hence should increase the use of knowledge in future endeavours, especially when problem-solving conditions are similar to the original conditions in which the knowledge is acquired. Learning groups are expected to produce a greater degree of knowledge transfer in contrast to individuals as they are expected to engage in more active learning. However, there is an important related element to this principle.

Bransford et al (1986) have suggested that when experts acquire knowledge as perceptual problems rather than facts, they learn to notice patterns and encode knowledge that is *useful*. Pattern recognition and perceptual differentiation (based on finding, noticing, comparing and contrasting problem features) lead to conditioned knowledge (Simon 1980) where condition–action pairs become the basis for spontaneously accessing knowledge (without being told to do so). Their results show that when perceptually anchored environments afford the learner the opportunity to perceptually discriminate among salient events, and the learner experiences changes in their own beliefs and assumptions, conditioned knowledge is likely to incur. Hence, they have developed a number of perceptually anchored environments (Cognition and Technology Group at Vanderbilt 1993) termed macrocontexts that (1) provide a common ground for learning about a problem and (2) provide goals for challenge problems that require learners to decompose an ill-defined problem. In particular, the use of video-based macrocontexts has been studied as an effective means of producing transfer of knowledge. But primarily these environments have only been used to assess individual learning. To extend our hypothesis, it is expected that a perceptually anchored macrocontext will facilitate knowledge transfer for both individuals and groups when the transfer problem is similar to their acquisition problem.

Socio-Cognitive Factors in Learning

As mentioned earlier in the paper there are many reasons to account for success (or failure) in individual or cooperative learning. The paper has put forth the salient theoretical foundations considered to be key in assessing what counts for success. However, any assessment of what counts for success may be incomplete without paying attention to the socio-cognitive influences derived from studying learning in more applied settings as well (see Gray 1989). Young and McNeese (1995) pose 10 *socio-cognitive factors* (distilled from both theoretical and applied research literature) expected to influence the acquisition and transfer of knowledge in CL settings:

1. CL requires the coordination of multiple cognitive processes, applied through multiple paths (Siegler and Jenkins 1989). Examples include analysis, planning, problem identification, metacognitive monitoring and problem solving while comparing multiple solutions to multiple subproblems.
2. CL occurs within complex contexts that provide critical perceptual cues and rich situational affordances (Rogoff and Lave 1984).
3. CL is interpersonal (Greeno et al 1993).
4. Being interpersonal, CL requires the social construction of knowledge (Bereiter and Scardamalia 1989; Edwards and Middleton 1986).
5. CL is often ill structured and requires generation of relevant subproblems (Cognition and Technology Group at Vanderbilt 1992).
6. CL involves the integration of distributed information, typically from various specialties and domains (Pea 1988).
7. CL takes place across extended time frames.
8. CL involves several possible competing solutions (Meacham and Emont 1989).
9. CL involves discovering problems and noticing perceptual attributes of the problem, such as detecting relevant from irrelevant information (Bransford et al 1986).

10. CL involves inherent values, intentions and goals that often have personal and social significance (Johnson et al 1988).

The Jasper series (12 different videodiscs portraying unique problem spaces) has been used as a broad experimental context to conduct research on the entire set of socio-cognitive factors. The selected macrocontext used for this study, *Rescue at Boone's Meadow: The Adventures of Jasper Woodbury*, is specifically attuned to focus on the basic research questions identified earlier. Reviewing literature in individual and group cognition (as pertinent for learning processes) found the roles of distributed cognition, perceptual cues, social construction of knowledge, subgoal generation, collective induction–integration, problem finding and discovery and multiple solution path considerations to be most salient for impacting learning processes. Socio-cognitive factors 1, 2, 4, 5, 6, 8 and 9 therein have been chosen as most representative for experiment assessment given the goals presented in the basic research questions. Factors 3, 7 and 10 although important tend to be more clearly related to social psychology concerns and deal more with interpersonal relationships, values and long-term commitments; all of which fall outside the purview of this study. Prioritisation of the most salient factors is also required to address practical constraints in creating a feasible experimental design and for considering complexities resident in protocol analysis.

A further delineation of the socio-cognitive factors is possible according to the type of research question asked. Factors 1,4 and 6 are expected to influence to the extent to which learning groups perform better than individuals in complex problem solving (research question 1); factors 2, 8 and 9 are expected to influence differences between cooperative and individual learning in promoting knowledge transfer (research question 2); and factors 1, 5 and 9 may discern the circumstances under which cooperative learning is effective and show the value of CL. Although the factors are shown as clustered around specific research questions, one can see that they also seem to be partially correlated with other questions as well.

Based then on the elaboration of theoretical foundations and the research questions posed, the selected factors are experimentally assessed. The study uses protocol analysis to differentiate among the kinds of activities that occur in individual and CL settings to assess whether the factors influence what counts for success. This analysis also evaluates how well these factors affect transfer functions. The idea of sharing individual knowledge through co-operative activities underlines the metacognitive/cognitive benefits of having people work together. Collective induction, generative learning and metacognition may play an intricate part in acquiring, constructing, transferring and remembering knowledge.

If CL groups do better at solving problems than individuals (for an initial problem), one would predict better transfer from members who participated in the cooperative (rather than an individual) learning setting when encountering similar problems in new situations. This would suggest the presence of collective induction activities in the learning group (beyond what the best member could do) that would be beneficial for subsequent individual learning outcomes.

METHODS

Subjects

A total of 56 subjects were randomly assigned to two experimental conditions (cooperative or individual learning) and served in the acquisition, transfer and recall stages of the study. All subjects were paid university students acquired through Logicon Technical Services, Inc. at the Air Force Research Laboratory. Subjects included only those students within the 18–30-year-old age range. Subject requirements also included having basic math skills and self-reported or corrected-to-normal 20/20 vision. Due to the nature of the content problem, any subject who had received exposure or graduated from pilot's training was excluded from the studies. Because college students were used they were not considered experts in the subject domain knowledge. In this case, any leadership or dominant behaviour was not derived as a function of specific domain knowledge or level of expertise on the part of the subjects (see Fig. 1).

CL teams consisted of two-person dyads that were not previously acquainted with one another. Instructions indicated that the team members were to jointly solve Jasper. Two-person dyads are defined as a team interacting interdependently to achieve a common objective which is consistent with definitions of teams (Cannon-Bowers et al 1993; Rentsch and Hall 1994). Although teams with more members could be used in future studies the efficiency of working with dyads is desirable for managing many group-level variables. Larger groups can introduce difficulties into delineating cognitive processes and interaction parameters, as well as promote undesirable coalition formations which may lead to competition rather than cooperation (Dansereau 1988). There were no specific (or separate) roles or responsibilities required for each member other than to work together. Social interaction between dyad members was indicative of the initial formation stage of group development.

Design

A perusal of Fig. 1 indicates that all subjects participated in two sessions that comprise the three stages of study. Session 1 includes the acquisition and transfer problems and lasts

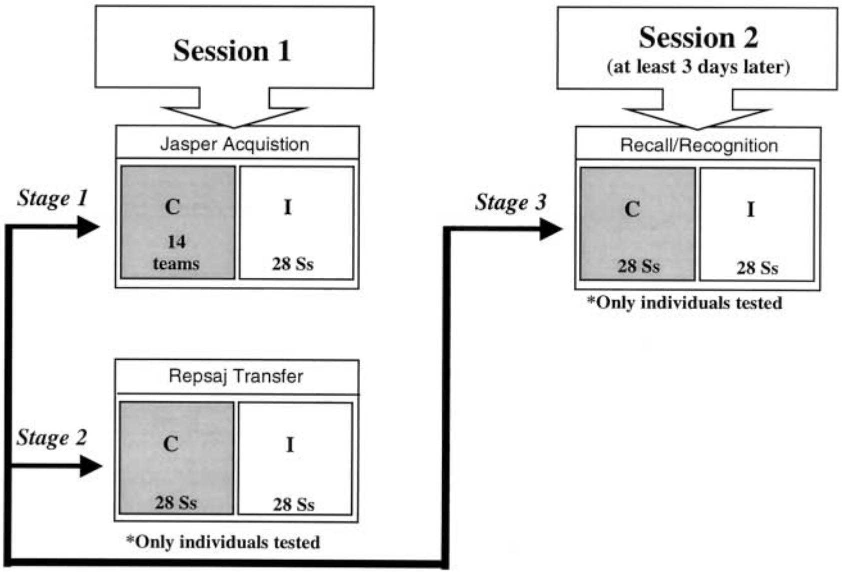

Fig. 1. Experimental design overview.

for approximately 2.5–3 hours. Session 2 occurs at a minimum of 3 days after session 1, lasts for approximately 1 hour, and includes only the recall/recognition problem. For the acquisition problem, 14 teams (composed of two people each) served in the CL condition while 28 subjects served in the individual learning condition. All of the subjects were individually given the transfer problem to solve. If a subject served within the group condition for the acquisition, he/she received the transfer problem as an individual only. This is representative of the *group-to-individual-transfer* paradigm. If a subject served as an individual in the acquisition problem, he/she continued solving the transfer problem as an individual. This provides the control condition, termed *individual-to-individual-transfer*, which may be compared to the *group-to-individual-transfer* condition to evaluate the effects of CL in analogical problem solving.

Task Description/Requirements

The study uses the *Jasper* planning macrocontext (see Cognition and Technology Group at Vanderbilt 1993) to assess the viability of socio-cognitive factors in learning and working together. As a macrocontext the Jasper paradigm provides a computer-controlled, video-anchored environment that presents an ill-defined story problem to either an individual or a team (dyad). Jasper incorporates a search and rescue mission involving an ultralight aeroplane to save an injured eagle in a remote location. The problem provides learners with a two-part challenge problem: (a) what is the quickest way to move the eagle? and (b) how long will that take? These challenges must be decomposed into a series of interconnected subgoals. The problem–solution space of each subgoal must be thought out as to alternative routes, modes of transportation and individuals available to save the eagle. There are a number of trade-offs which must be calculated with each alternative solution proposed, relevant and irrelevant information must be discerned, and decisions must be made to see if the best possible solution has been derived (all within a limited timeframe).

The Jasper macrocontext is flexibly open-ended when it comes to a team establishing level of interdependency. Therein, the team must decide jointly how to solve the problem but each member is not specifically dependent on the other member in a structured way. There is no difference between the individual and CL version of Jasper in terms of the demands of the task requirements. However, individuals may interact with it in a different way from that of a dyad (in terms of the processes they invoke to solve it). The goal behind the creation of Jasper was to implement an ill-structured planning task which affords learners the opportunity to identify, define and discover their own problems within a natural domain (i.e., a macrocontext) while taking temporal, spatial and practical interdependencies into account.

Repsaj, the individual transfer task in this paradigm, is represented as a verbal analogue of the Jasper problem. The Repsaj task is represented as a word story format similar in storyline and solution procedure to Jasper. The underlying structure of Repsaj is the same as Jasper, but the surface structure and mode of representation vary. For example, the Jasper domain involves an ultralight aeroplane being used in search and rescue to save a disabled eagle shot in a forest. The goal of this problem is to find the most efficient way to get the eagle to the veterinary surgeon before it dies. In contrast, the Repsaj domain involves a lightweight plane used to rescue an injured Air Force officer who has contracted frostbite while on manoeuvres in a remote region of Canada. The goal of this problem is to find the most efficient way to rescue the officer and transport her to the nearest medical facility. The surface themes that relate the two problems are similar rather than dissimilar. Although the domains have different specifications they are connected by the fact that they both involve operations and specific knowledge of aircraft and their flying capabilities, as well as rescue missions. In each problem, the solver must pay attention to the characteristics of the aircraft (e.g., payload capacity) and other vehicles involved to: (a) know the boundary constraints and (b) create the plans, which lead to the most efficient trade-offs at the right point in time. As there are many similarities between the two problems, they may be classified as close analogies of each other. When Repsaj follows Jasper, the situation for near-term transfer of knowledge exists.

Apparatus

The apparatus used includes a Macintosh® computer system interfaced to (1) a Pioneer 2200® random-access, laser disc player and (2) a Magnavox® 14-inch colour monitor. This video workstation (for use by the subject) has the capacity to display laser videodiscs, text and graphics, and interactively control access to the laser disc through the computer keyboard or mouse. A timer signal is used to collect timing data on the subject. Other apparatus included three 14-inch colour monitors for the experimenter's station, a clock for subjects to use, and three colour video cameras with an integrated microphone system linked to a VCR to record subjects' problem-solving behaviour. A program resident within the Mac was designed to record all the commands an individual or group made while interacting with the laser disc-based Jasper problem. These computer records can then serve as evidence to review the extent/content of perceptual contrasts that a person makes while solving Jasper.

Measures

Four distinct kinds of measures were used: problem space measures, statement type measures, performance measures and recall/recognition measures. The measures allowed an in-depth comparison between the individual and cooperative learning conditions to examine the extent to which subjects reason and make decisions involving ill-defined problems. They were specifically used to assess what was attended to and through what path, how the solution emerged with what processes, the level of the learner's comprehension, the value of the solution, the extent to which a dominant member of a team influenced problem solving, the degree to which the problem identification and solution transferred, and how much information was remembered. The measures specifically showed evidence for the extent that socio-cognitive factors (e.g., collective induction, perceptually based transfer of knowledge, metacognition) are operative in learning and track the subjects' pattern of responses to the Jasper/Repsaj challenge problems.

The study employed (1) problem space and (2) statement type protocol analysis measures similar to those used by the Cognition and Technology Group at Vanderbilt (1993; Goldman et al 1991). The scoring of a group or individual transcript is based on evaluation of the *problem elements* and *statements types* occurring in the transcript. This is related to planning net analysis as described by Van Lehn and Brown (1980) where elements of the solution space are analysed.

The Jasper problem space may be segmented into different types of subproblems that a problem solver can attend to. Some of the subproblems are considered to be more surface level and consequently easier for subjects to do (e.g., mention aircraft range, mention payload constraints, mention time component (as part of distance = rate × time equation)). As subjects become familiar with these surface-level elements of the problem space they recognise that they need to attempt to solve some of interconnections between elements of the problem to achieve the challenge required of them. Therein, they begin to attempt to solve for range, time and payload, which are scored as well. If subjects actually solve the embedded subproblems for these elements that is also scored as part of the problem space markers. Finally, subjects begin to drill down and realise the deep structure of the problem that requires them to consider multiple constraints and make effective trade-offs among elements in the problem. These are the hardest subproblems for subjects to solve for. They are represented as whether they considered where they can land an ultralight (it requires a minimum distance for a landing strip) to save the injured eagle in the problem, whether they have considered multiple pilots to fly the ultralight (there are various options to consider as each potential flyer is at a differing location and has different weights, which affect payload), multiple vehicles (subjects have options to use different locomotion options (car, truck, ultralight, walking) to get to the remotely located forest where the eagle is injured, multiple routes (subjects may consider various routes which pose different distances (and obstacles) dependent on which pilot, vehicle and landing strip options are available for their solution plan), and whether the subjects generate multiple plans to compare times of each plan to see if it is the optimal time (i.e., least amount) to rescue the eagle and whether there is enough time to get the eagle back to the veterinary surgeon to save the eagle. The problem space measure represents the percentage of subjects in a given condition that obtained the specific subproblem element under question (from surface to in-depth levels) with the Jasper problem. For example, 30% of the individuals solving Jasper may have obtained the 'range solved' element, in contrast to 60% of the cooperative learners who obtained the 'range solved' element. We also used a percentage of the 'total problem space elements solved' measure to represent the total amount of subproblems obtained by subjects. For example, if a subject scored 70% it would indicate that the person had obtained 70% of all possible problem space measures as revealed by their protocol. This measure is used as a summary outcome.

Looking at the primary summary measure provides a holistic view of the problem space. To reiterate, for Jasper this is defined as the percentage of problem elements solved. This variable portrays a total score in the problem space as it represents how well subjects did by scoring the percentage of problem elements they obtained out of the total available. This summary variable includes whether subjects mentioned, attempted or solved the elements involved for each feasible route (payload, range and time) and their consideration of each identified optimising solution element. Each element had equal weight in computing the percentage they obtained out of the total possible. The primary summary variable for Repsaj is the percentage of problem elements transferred. This represents the percentage of the elements initially obtained in Jasper which were maintained for Repsaj. For example, if subjects mentioned payload in Jasper and then mentioned it again in Repsaj, this would indicate that they had transferred this single element. The score thus represents the total amount of elements transferred from Jasper to Repsaj.

A more specific component of the problem space measure (for both Jasper and Repsaj) assesses how well subjects did on attempting, mentioning or solving particular task constraints (payload, range or time) for each feasible route in the planning space. This component explicates problem solving on *less complex* aspects of the problem space. Routes were also examined to determine if the optimal solution path was discovered and solved (solution quality). Recognising and solving for the 'optimising elements' within Jasper reveal activity concerned with the *more complex* parts of the problem space.

An example of the problem space analysis is applied to the following excerpt from a transcript that shows a subject thinking through the payload element of the planning net:

She is 120 lbs let me move through the video disc there it is, he weighs 180 lbs. So I am going to move ahead and add some of this stuff up. The eagle is 15 lbs, and the carrying box [on the ultralight plane] is 10 lbs, and the fuel weight is 30 lbs so you get 235 lbs total. So he can't fly it [as it is over the specified payload limit]. She will have to fly it. Yeah, she fits 55 + 120 . . . 175 lbs.

This short excerpt demonstrates identification of certain facts pertaining to the payload component of the problem, a successful attempt to solve the total weight requirements, and shows the subject has solved the substitution insight (i.e., replacing one pilot with another who weighs less and thus satisfies payload limits). Therefore, for the problem space analysis this subject would have a positive score for *mentioning facts* (weights of objects in this case), *attempting to solve* for total weight of the items needed to fly a rescue mission, and *solved payload exchange* elements of Jasper. This payload sequence is just one of the simpler subproblems that must be addressed as a first-level condition in order to solve the larger challenge problems. As subjects pursue different solutions (e.g., figuring multiple routes for the planned rescue using multiple vehicles) they must compare times to see if they will be able to rescue an injured eagle in an adequate timeframe. As they try out different solutions, other aspects of the subproblems may change that may require them to consider new constraints and hence change the values for solutions. This is all part of the complexity of Jasper that requires multiple considerations to keep in mind. When they began to consider plans and outcomes associated with multiple vehicles, multiple route selection and comparing times, then they have advanced to the core complexity of the problem space and are also scored appropriately for how well they attempt, mention and solve these more difficult subproblems.

Statement type measures were also collected and analysed as part of the overall protocol analysis process. The statement type measure was obtained by rating each protocol statement according to a structured template as to whether very specific instances of problem-solving activities were present in their statements (e.g., goals, states, means, outcomes, metacognitive monitoring, misconceptions and 'other' categories). For example, the phrase 'I want to choose a vehicle' would be scored as a goal, or 'There are no roads leading to Boone's Meadow' is a state, or 'How can I figure out if there is gas in that can or not?' is a metacognitive statement. After collapsing across specific instances to form a sum total of statements in each category, the number of statements in each category is divided by the total number of statements in a subject's protocol to compute the percentages for each statement type generated by a subject.

The statement analysis hence shows the percentage of statements (out of all the possible statements) encoded for a given category. For example, an individual's transcript may consist of 10% 'goal' statements, 25% 'state' statements, 5% 'means' statements and so on.

For each protocol analysis performed, cross-reliability checks between raters were conducted in accordance with the procedure used by O'Donnell et al (1988). For the problem space analysis raters scored a subject's or a group's protocol through the use of a template which contained the total subproblems that could be addressed by a subject. A group's protocol was treated as if it were an individual protocol. For the statement analysis, raters encoded each statement in accordance with the problem-solving activities available in analysis (e.g., goal, state). Results showed an 88% correlation for the problem space protocol analysis and 96% correlation for the statement encoding (Pearson $r = 0.96$, $p < 0.0005$). Protocol analysis measures are complemented by performance measures: time on task, number of times the Jasper video is accessed and recall/recognition measures. Video access represents the number of initiatives recorded to access the Jasper laser disc wherein a subject or a group would review a video segment of the Jasper problem as part of their problem-solving sequence. Recall/recognition measures are tests consisting of multiple-choice and fill-in-the-blank questions assessed after the transfer task was completed – three to nine days later.

Procedure

As part of the instructions, subjects must listen to an audio tape that gives an example of a person 'thinking aloud' in response to being asked to explain the humour of a cartoon. The instructions request subjects (both individual and learning group conditions) to talk aloud as they solve the problem and to speak as items related to the problem come to them. Subjects are then asked if they have questions and if they know what they are supposed to do. They are asked to generate the best solution and not to make assumptions beyond specific evidence from the storyline. For the learning group condition, the dyad is asked to solve the problem together but no other restrictions are required. If subjects are silent for a long period of time the experimenter asks them to talk. After a learning group or an individual receives their initial instructions, the full-length Jasper video (approximately 17 minutes) is presented without interruption. Subjects are asked not to take notes during presentation time. After the problem has been presented, a timer initialises recording of subjects' behaviour and they begin problem solving. After 60 minutes, subjects are asked to stop their problem-solving activities. When subjects are done solving the acquisition problem, they signal the experimenter. The experimenter asks them to give a summary of their solution steps and then they are released from the acquisition problem. At this point, subjects are required to take a break. After the break, all subjects return to participate in the filler task, which acts as a momentary interference factor before starting the transfer problem. The experimenter informs subjects that the filler task is a survey required by the experimenters to obtain biographical and problem-solving preferences from the subjects.

The transfer task is presented entirely as a verbal story problem for all subjects and is solved individually. Each subject is given about 5–10 minutes to read the problem, then recording of their behaviour begins as the experimenter signals they may begin work. The subjects are allowed a maximum of 40 minutes to complete this task. After the transfer task, they are required to turn in all their written materials and are reminded to return in three days (minimally) for Session 2.

Upon arriving for the recall session, subjects are given a test booklet that contains the memory recall/recognition task. When subjects begin a timer is initiated to record subjects' response times. Subjects have up to 30 minutes to complete the booklet When subjects are done with the recall task, they are debriefed and then dismissed.

RESULTS

Cooperative Learning Components: Jasper Problem

Cooperative versus individual learning settings are analysed to reveal the various factors contributing to differences in conditions. The primary summary measure, percentage of problem space elements obtained, showed a significant main effect of learning setting ($F(2, 53) = 3.21$, $p < 0.008$). Also, according to Hotelling-Lawly's criteria, the MANOVA results showed an overall significant main effect for learning setting for the statement type measures ($F(10, 96) = 2.58$, $p < 0.008$) and performance measures ($F(6, 98) = 2.76$, $p < 0.016$). Based on these findings, an analysis was conducted to see whether groups do better than individuals. Individual comparison tests performed on the primary variable revealed that groups ($m = 75.51$) do better than individuals ($m = 61.48$), ($t = 2.41$, $p = 0.02$).

Statement type measures were also analysed to complement the problem space analysis. Refer to Fig. 2 for the

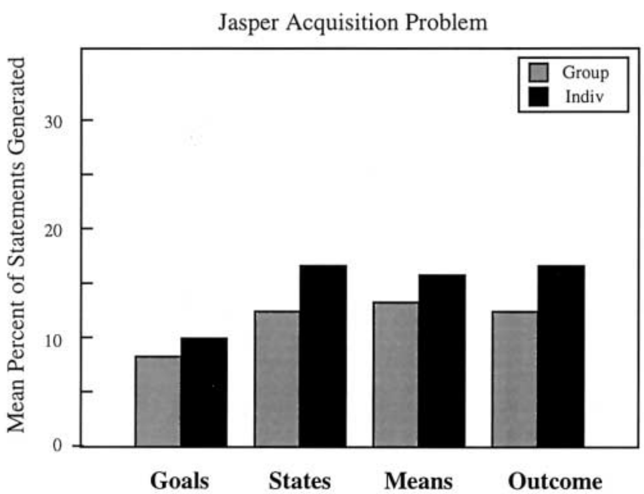

Fig. 2. Learning setting analysis (goal–mean–state–outcome statements).

following set of results. Each individual or group transcript could be reviewed to see the relative percentage of statement categories that formulate patterns of activity. Activities such as identifying states, defining the means to relate states with goals and calculating outcomes are indicative of activities that centre on stating facts, procedures and solutions. These activities relate to the details of the Jasper task at hand. For percentage of 'states' generated, individuals (m = 16.79) produced more than groups (m = 12.64), (t = 2.31, p = 0.02). This trend is maintained for percentage of 'means' generated. Individuals (m = 15.76) produced more than groups (m = 12.86), (t = 1.99, p = 0.05). The trend continues for percentage of 'outcomes' generated as individuals (m = 16.66) produced more than groups (m = 12.21), (t = 2.65, p = 0.01).

By comparison, activities such as generating goals, identifying misconceptions, pursuing metacognitive monitoring and 'other' activities centre on problem identification, argumentation, affective states, catching errors and planning. These kinds of statements focus beyond the details of the problem per se and emphasise some of the problem-solving strategies used to assimilate the problem. The analysis revealed a partially reverse pattern for these activities as shown in Fig. 3. For percentage of 'goals' and 'misconceptions' generated, there were no significant differences among the learning setting conditions. However, for percentage of 'metacognitive monitoring statements' generated, groups (m = 34.45) produced more than individuals (m = 26.17), (t = 3.18, p = 0.002). This trend continued for percentage 'other' statements generated as groups (m = 17.16) produced more than individuals (m =12.46), (t = 3.18, p = 0.05). These statement analyses show clear differences in how groups vary from individuals on their problem-solving activities.

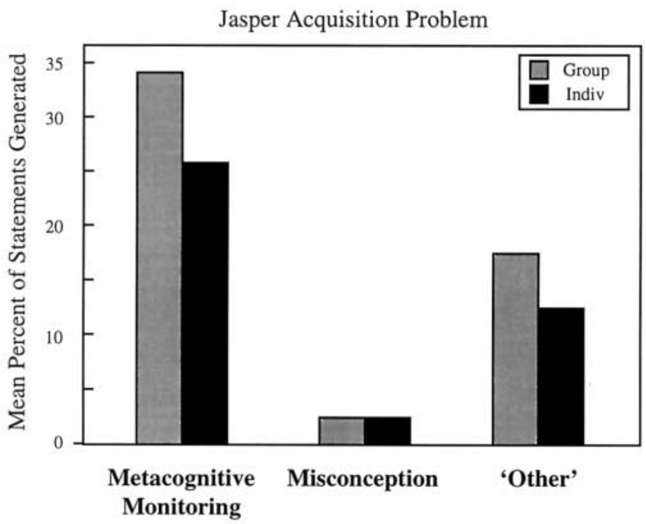

Fig. 3. Learning setting analysis (metacognitive–misconception–other statements).

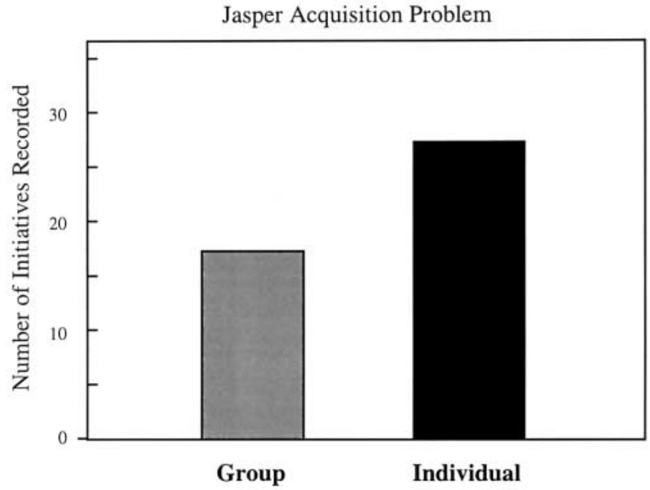

Fig. 4. Number of initiatives recorded to activate Jasper video disc.

The performance measure, number of initiatives recorded on the laser disc, nicely complements the statement analysis as it also highlights differences in the pattern of activities between groups and individuals. The measure represents the extent to which a subject perceptually experienced and utilised the video disc for contrasts, comparisons and searches for relevant information in the Jasper macrocontext. Figure 4 shows that individuals (m =27.64) accessed the Jasper video disc more than groups (m =17.54), (t = 2.49, p = 0.01). This performance measure reinforces the idea that individuals emphasise different approaches to Jasper learning.

Transfer of Learning Components: Repsaj Problem

Jasper results clearly identify advantages for CL when compared to individual learning settings. Like many previous studies, this reinforces the idea that CL is a worthwhile endeavour. Groups primarily engaged in metacognitive activities (and secondarily explored the macrocontext) while individuals primarily explored the macrocontext (and secondarily participated in metacognitive activities).

A remaining issue is to see if these advantages transfer to the near-term analogy problem (Repsaj) when individuals act alone. The first objective is to see whether participation in the CL setting facilitated continued success on the Repsaj problem. The second objective is to see whether the level of collective induction affected transfer on Repsaj. Finally, the third objective is to compare the dominant member and the passive member of the dominant group with each other and the individual learning setting to see if these conditions show different transfer results.

The first issue is whether the cooperative or individual learning setting (as experienced in Jasper) facilitated individual performance on Repsaj. The primary summary measure for transfer, percentage of problem elements transferred, indicated a significant difference between group-to-individual and individual-to-individual transfer. Individuals (m = 84.3%) transferred more overall problem elements than did members of Jasper groups (m = 73.37%), (t = 2.81, p = 0.0076).

The Repsaj statement type analysis identified distinct advantages for members who were initially in *shared groups* (sharing defined by relative equivalence in the amount of talking between the subjects which suggests collective induction while solving Jasper). Members in shared groups (m = 10.22) produced significantly more goal statements on Repsaj than those in dominant groups (m = 8.14), (t = 2.42, p = 0.03). Shared group members (m = 26.88) produced a greater percentage of means statements than passive members of the dominant group (m = 21.15), (t = 2.31, p = 0.04). Results approaching significance show that shared group members (m = 26.88) tend to produce a greater percentage of means statements than dominant group members (m = 22.95), (t = 1.81, p = 0.0.095).

Alternatively, members initially in dominant groups (m = 23.49) for Jasper tend to generate a greater percentage of states than do members in shared groups (m = 19.22), (t = 2.15, p = 0.053), or even individuals (m = 19.89), (t = 1.82, p = 0.078) although these comparisons only show results approaching significance. The passive members of the dominant group (m = 23.80) tend to produce a greater percentage of states than individuals (m = 19.89), (t = 1.82, p = 0.078) although this comparison only approaches significance. There is tentative support here for the original hypothesis that shared groups actively generate useful learning activities (and specific knowledge) during acquisition, which in turn helps transfer performance. Yet, one can see exactly where they benefit on Repsaj. They excel in the goal-setting activities and in coming up with the means to produce the solution. In other words, individuals who were in shared groups show advantages on more problem-solving-based activities working individually on Repsaj.

The single advantage (or perhaps disadvantage) for members in the dominant group was that these individuals produced a greater percentage of 'states' type of statements for Repsaj. This shows a strong necessity for maintaining the dominant group's initial orientation in Jasper. They dwell on details and search for facts at the exclusion of spending more time thinking about subgoaling, alternative solutions or identifying the problem in different ways.

The passive members of these groups spent more time on Repsaj (than individuals) trying to find the facts, perhaps to the point whereby they lose sight of actually solving the problem. In these situations, it may be worse for one to be in a group dominated by one person than it would to have acquired knowledge individually. This is an example that shows how *group process loss* can affect subsequent transfer activities (for an individual who previously solved an analogous problem in a dominant group). Hence, certain conditions of CL are not always healthy for helping a person use their knowledge when they encounter similar problems in the future.

The Repsaj performance measures show that members initially in dominant groups for Jasper spent more time completing Repsaj in contrast to other conditions. For example, dominant group members (m = 30.38) spent more time completing the Repsaj problem than shared group members (m = 22.67), (t = 2.50, p = 0.03). Other comparisons approaching significance indicate that dominant members of the dominant group (m = 33.75) tend to spend more time completing the Repsaj problem than individuals (m = 27.44), (t = 1.82, p = 0.078) or passive members (m = 27.00), (t = 1.99, p = 0.066). Apparently, the dominant group member does not quickly access knowledge for use on Repsaj. Perhaps one hint is that these dominant individuals spend too much time stating the facts rather than subgoaling/planning a solution. What transferred for the dominant group member was the propensity to be tied to the details of the problem.

No other significant findings were found or reported here. In particular, results associated with the recognition/recall stage of the procedure produced non-significant results.

DISCUSSION

As shown in this research, cooperative learning may occur under a myriad of circumstances and situations, and may be defined differently dependent on one's goals and perspectives. The study undertaken and presented in this paper is predicated by three basic research questions:

1. Do cooperative learning groups do better than individuals at solving complex problems?
2. How do cooperative and individual learning processes differentially affect transfer to similar problems?
3. What circumstances make cooperative learning valuable? How do socio-cognitive factors influence learning processes?

At the core of these questions is the idea of what it means to 'cooperate'. The theoretical perspectives regarding this idea have been presented along with the derived socio-cognitive factors expected to influence the effectiveness and success of CL. These specific factors were hypothesised as salient in determining answers to each of the above questions.

When Cooperative Learning Transpires

After reviewing the results, the *actual effectiveness* of these factors may be summarised from two perspectives (which collapse across various factors): (a) cognitive benefits accrue when people *naturally* work together, and (b) learners need the opportunities to generate, discover and notice perceptual aspects of knowledge in a situated context. The first perspective centres on collective induction and metacognitive learning strategies (Young and McNeese 1995 – factors 1, 4, 6) and is initially more specifically related to research question 1. The second perspective (encompassing factors 2, 5, 9) suggests that if knowledge is acquired in a situated problem within a perceptual context, there is a greater chance that knowledge can be spontaneously accessed during 'uninformed' conditions (i.e., a person is not told what to do or recall); see Bransford et al (1988). This perspective relates more to research question 2 for now. Both perspectives fold into research question 3, which has a broader focus. The results reveal that indeed these factors help clarify what counts for success in CL. The results clearly support previous work in CL (Johnson et al 1981; Dansereau 1988) and reinforce our hypothesis that groups would in general do better on the Jasper problem than individuals, hence providing an answer to question 1. It appears that the help of another problem solver provides a synergy which is most useful for consideration of the most complex, optimising elements of Jasper. Hence, these findings suggest that cognitive benefits ensue while working in a situated CL setting.

In contrast to findings that trumpet the success of cooperative work, this research clarifies the use of the Jasper macrocontext by groups versus individuals. Socio-cognitive factor number 2 emphasised situated context as a basis to experience a problem, thus providing the opportunity for learners to notice and generate attributes relevant to the problem. The results show that *individuals* actually spent more time with the macrocontext than was the case for group problem solvers. Consequently, individuals have more perceptual learning experiences and maintain a stricter use of problem details as cognitive tools. This approach may allow a problem solver to condition his/her knowledge to perceptual anchors to create a forward chaining effect across similar contexts (Greeno et al 1993). This may afford effective recognition of constraints/conditions in future situations that have similar attributes to those experienced in the original situation, thus resulting in the spontaneous reuse of previous knowledge.

In contrast, it appears that *cooperative learning groups* are quite dependent on metacognitive strategies to come to a solution, and although they use Jasper as a perceptual base for problem solving they explore it much less than individuals. This result provides evidence for at least a partial answer to question 2. These results can be interpreted by suggesting that group process is very distributed, thus lending support to socio-cognitive factor number 6. The *external group memory* reduces the necessity to access the video disc for retrieval of raw data as members contribute what they know. The group has more discussion about alternative plans regarding the problem space but explores the perceptual representation less. The 'external memory' reduces the necessity for any given member to have to rely on limited generation of knowledge (and thereby retreat to the macrocontext to retrieve the data required to solve the problem). The statement analysis supported this finding by showing that individuals engage in activities that are highly related to the Jasper details and facts; whereas groups typically are more distributive in their approach to problem solving and focus more on metacognitive strategies. This finding also provides evidence for socio-cognitive factor 1, coordination of multiple cognitive processes through multiple solution paths.

What Does Cooperative Learning Transfer?

An answer to question 3 is provided as the value of CL is definitely contingent upon the presence of specific socio-cognitive factors that explicitly change problem-solving/transfer outcomes. Evaluation of results informs a deeper understanding of CL, shows how socio-cognitive factors are involved in trade-offs in outcomes, and yields assessment of the underlying circumstances where CL is successful. The hypotheses one can make regarding transfer of knowledge are directly related to the socio-cognitive factors relayed in the previous section. How is transfer affected by the cognitive benefits of having people work together? How is transfer affected by the benefits of actively generating knowledge within a highly perceptual-based situated context? For Jasper, we provided evidence that groups engage in collective induction and metacognitive strategies and generally approach the problem differently from individuals. Individuals were more inclined to focus on details and explore the perceptually based macrocontext.

The original prediction put forth was that transfer performance would be quite good as the initial situated context (Jasper) affords perceptual learning. The experience of discovering different problem features (e.g., factor number 5, 'generate sub-problems') can be transferred to and useful for Repsaj. However, this prediction assumed that groups and individuals would both maintain relatively equal exploration of the context. The Jasper results clearly portrayed individuals (and to some extent dominant groups) spending much more time exploring the macrocontext than shared groups. Given these results, the expectation is that individuals would transfer more than groups as they spent more time in the problem's perceptual context differentiating details. Alternatively, the role of collective induction predicts that sharing groups should generate more knowledge, insights and ideas beyond what a dominant group or individual would do, and thereby would transfer this 'cognitive benefit' to Repsaj.

The interesting results obtained for Repsaj found that each of these expectations turned out to be true for different aspects of transfer. That is, *transfer effects* for the Repsaj problem space can be measured by two distinct components: (a) transfer on the more complex parts of the problem and (b) total transfer of problem elements (giving equal weight to problem elements). This finding – in addition to the findings mentioned for Jasper – provides a broader, more complete, answer to research question 2.

People who participated in shared or dominant groups when compared to the individuals solved the complex parts of Repsaj better. Alternatively, for the measure – total transfer of elements – individuals did better than either group condition. Hence, groups appear to benefit from working together and exchanging metacognitive strategies that enhance problem solving on the hardest parts of Repsaj. Individuals benefit from spending more time in the macrocontext that enhances the overall transfer of problem elements. The approaches taken by groups or individuals for the Jasper problem hence created differential return on investments, contingent on the specific components of transfer which are investigated. Socio-cognitive factors influence groups very differently from individuals when determining 'what transfers' in situated, real-world learning.

Groups showed that even though their collective induction facilitated transfer for the more complex parts of Repsaj, their lack of exploration in the macrocontext left them with limited transference of those problem elements not accessed or sufficiently explored in the video disc. Groups may not explore the macrocontext as much as individuals owing to their distributed nature, perhaps a case wherein the factors 'trade off' cognitive benefits. Young and McNeese (1995) imply that for collective induction different members generate new ideas that are synergised in the group setting (factors 1–4–5). Often, this results in identifying new problem directions or provides alternative solution paths for an ill-defined, complex problem (factor 8). Groups may rely on each other for a kind of externalised transactive memory system (see Wegner 1987, 1995) rather than searching through the Jasper video disc for that information. As implied by factor 6, this 'distributed intelligence' (Pea 1988) facilitates more collective induction and metacognition but reduces a group member's exposure in the context. These observations supply answers for question 3 as they suggest how 'circumstances' are actually influenced by the combinations of socio-cognitive factors and in turn significantly affect learner outcomes.

Another perspective on the distributed component is that there is less necessity for each team member to address every aspect of the problem. Teamwork is shared or stratified according to situational needs, roles, goals, abilities and interdependencies of the group. One member may solve one component of a problem while another addresses a different component. McGrath (1990) refers to this as the tendency for groups to be partially nested and loosely coupled. Any member may construct different knowledge, which is then distributed to the other member as part of the solution outcome. Given an ill-defined, complex, multi-step problem like Jasper, such stratification of effort and responsibility is likely to occur. Concomitantly, when group members go on to solve similar situated problems as individuals, they only transfer the part(s) that they generated during acquisition. Other members may have generated other parts and since that individual did not construct them initially, or they may not have been shared in depth, they tend not to be transferred.

In contrast to groups, individuals do not have the luxury of relying on other members for knowledge, for memory of details, or to just localise their efforts for a particular component of the problem. They must generate everything on their own, take personal responsibility for every aspect of the entire problem, and use the macrocontext to access information/details of the problem. Indeed, the statement analysis clearly shows differing patterns of generative activity between groups and individuals.

The distributed/interdependent nature of group activities has theoretical and practical implications for CL and the transfer of knowledge. When the size of a learning group increases, collective induction possibilities may also increase as there would be greater distributed intelligence and more interdependencies among group members (up to a plateau and then process loss is activated). However, this decreases each group member's exploration and responsibility to the holistic requirements of the problem. Taken to a full theoretical position, metacognitive activity in larger groups helps the group member do better (in acquisition and transfer) in coming up with answers for the complex parts of the problem but promotes less total transfer for any given group member. Dependent upon the diversity of measures within a given CL study, these reciprocating findings may be masked and results may not show the total picture to understand the complexities in evaluating success.

Implications for Future Research

There are multiple perspectives, constraints and possibilities when it comes to assessing what counts for success in cooperative learning. The research reported here provides evidence for differences among individual and team cognition when it comes to a specific type of learning environment. To restrict generalisation of these findings it is necessary to emphasise that the results concerning socio-cognitive factors are specific to the type of teams used, the kind of tasks employed and the experimental methods/measures assessed.

The results were produced with dyads and thus may be considered applicable to dyads that are required to work together for the first time (i.e., unacquainted team members are commonly found in military teams, aircrews and ad hoc committees). These dyads are ones that have been given cooperative work requiring learning but without pre-specified roles. The type of tasks used suggested that real world, perceptually based environments are valuable for transfer of knowledge when challenges facing individuals require planning in the midst of ill-defined problems. Hence, results are salient for those dyads that may be interacting in a highly perceptual and dynamically changing world. Dyads like this exist in real-world settings (e.g., paramedics, police officers and detectives, surgeons, aviators, daycare providers, sports announcers and restaurant servers) and hence the results from the studies should generalise to these kinds of contexts. Because the Repsaj transfer problem presented a verbal analogue to solve, it made transfer more difficult in contrast to the case where the transfer problem could be presented as a perceptually similar analogy. However, one key point on transfer is that the Repsaj problem was a near-term analogy. Analogies that are far term (having a different deep structure of knowledge) may show different results. The results are useful for practical situated cognition settings where a great deal of real-world problem solving entails learning about cases and transferring near-term relationships for other similar cases.

One restriction also needs to be highlighted regarding dominant member versus shared learning groups. As this study only employed novices (subjects were not considered experts in any way), the interpretation of dominant member groups needs to be qualified with the realisation that the groups used here were not real-world work teams who had previous experience working together. In various naturalistic decision-making contexts, dominant members of teams who provide expert leadership, knowledge and advice may actually show different results. In our case, the findings are specific to more novice groups who work together for the first time on an ill-defined assignment. These novice kinds of work groups are very different from a group that historically develops a leader as a dominant member over time wherein specific personality, task knowledge and/or roles have more influence on a given situation. The results here are also predicated on individuals and teams working on ill-defined, challenging problems in contrast to well-defined, highly routinised tasks. Hence, interpretations should be kept close to these restrictions.

In conclusion, research findings have shown how socio-cognitive factors mediate problem solving and learning. These factors argue for the mutuality of agent–environment transactions as both context and cognition are defined in terms of the ways they mutually constrain each other and in turn determine what counts for success. The model presented here suggests that the social construction of knowledge is highly dependent on being situated within a perceptual context and having the cognitive benefits of working with others. Yet there are a number of different trade-offs that influence learning and the extent of knowledge that is transferred from one situation to another.

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